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**Development of an Aeroelastic Analysis Including
a Viscous Flow Model**

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DEVELOPMENT OF AN AEROELASTIC ANALYSIS INCLUDING A VISCOUS FLOW MODEL

Under this grant, the flutter versions of the three-dimensional Navier-Stokes aeroelastic code (TURBO-AE) have been developed. The TURBO-AE aeroelastic code allows flutter calculations for a fan, compressor, or turbine blade row. This code models a vibrating three-dimensional bladed disk geometry and the associated unsteady flow (including shocks, and viscous effects) to calculate the aeroelastic instability using a work-per-cycle or eigenvalue approach.

Steady and unsteady calculations have been performed with the 3D Navier-Stokes (TURBO) code to gain familiarity with the code. Calculations were done with the NASA Rotor-67 configuration which has been used as a standard test case by turbomachinery researchers. Additional calculations have been performed for the NASA/GE EEE fan and a proprietary configuration.

Four versions of the TURBO-AE code have been developed with following features:

Version 1	harmonic blade motion, zero phase angle only, work-per-cycle calculation.
Version 2	harmonic blade motion, any phase angle (requires multiple blade passages), work-per-cycle calculation.
Version 3	pulse blade motion, multiple phase angles (requires multiple blade passages), eigenvalue calculation.
Version 4	harmonic blade motion, any phase angle (single blade passage), work-per-cycle calculation

Routines have been developed to interpolate modal displacements from the finite-element structural grid to the TURBO-AE CFD grid, to deform the grid to account for the instantaneous blade deformation, and to calculate the generalized forces acting on the blade and the aeroelastic work being done on the blade. Routines have also been developed to implement the direct store method for phase-shifted periodic boundary conditions. The development and verification of versions 1 and 2 of the TURBO-AE code has been described in Refs. [1] and [2]. The development and verification of versions 4 of the TURBO-AE code has been described in Ref. [3]. Calculations have been done using different configurations including: flat plate rotor or helical fan, the tenth standard configuration, rotor 67, rotor 37, and the EEE fan.

References

- [1] Bakhle, M. A., Srivastava, R., Stefko, G. L., and Janus, J. M., "Development of an Aeroelastic Code Based on an Euler / Navier-Stokes Aerodynamic Solver," ASME Paper 96-GT-311, 1996.
- [2] Bakhle, M. A., Srivastava, R., Keith, T. G. Jr., Stefko, G. L., and Janus, J. M., "Development of an Aeroelastic Code Based on an Euler / Navier-Stokes Aerodynamic Solver," NASA TM 107362, 1996.
- [3] Bakhle, M. A., Srivastava, R., Keith, T. G. Jr., and Stefko, G. L., "A 3D Euler / Navier-Stokes Aeroelastic Code for Propulsion Applications," AIAA Paper 97-2749, 1997.